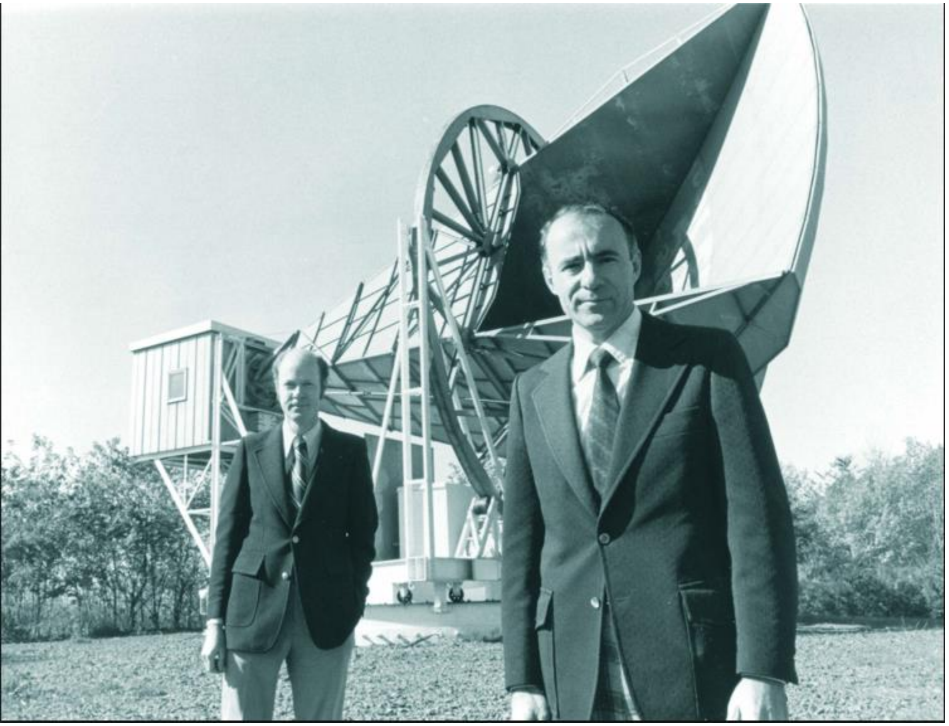
ROG

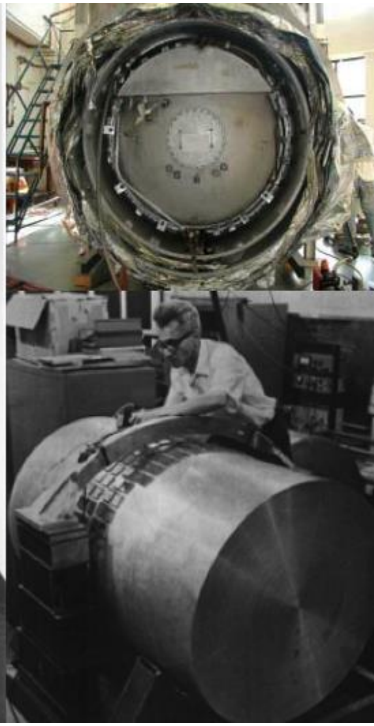
ricerca onde gravitazionali

gravitational wave research

During the sixties Amaldi tried to push the Italian physicists in the direction of new researches in the birth phase:

Infrared Background radiation and Gravitational Waves (after Penzias & Wilson and Weber's experiments).



# Weber started seeing things

In 1969, Weber made his first of many announcements that he was seeing coincident excitations of two detectors.

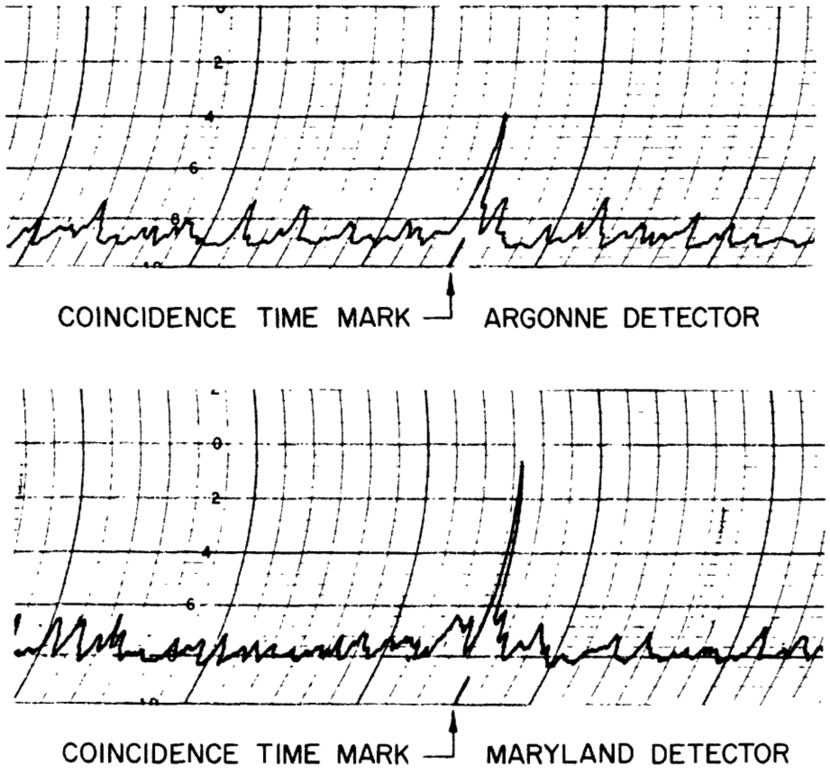
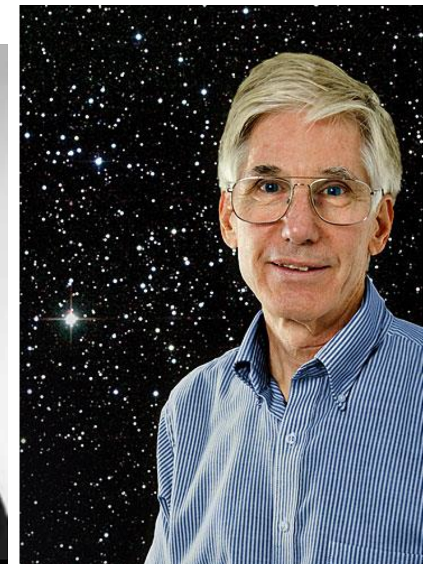



FIG. 2. Argonne National Laboratory and University of Maryland detector coincidence.

# Joining the quest …

Guido Pizzella, Rome

Richard Garwin, IBM

Tony Tyson, Bell Labs

Ron Drever and Jim Hough, Glasgow

Guido Pizzella was Amaldi's assistant and wanted to change its activity from space research (he worked with Van Allen in USA) to a more fundamental field. His decision was: Gravitational Waves (Francesco Melchiorri later choose the infrared background).

In the words of Guido:

"On September 3rd 1970, I said to Amaldi: *Professor, I want to make an experiment for the search of gravitational waves*. His eyes lighted and immediately we agreed to proceed. He informed me that Massimo Cerdonio was thinking how to use the SQUID, he was studying for biologic studies, for the search of GW."

## What kind of experiment?

(from the words of Guido Pizzella)

"In January 1971 Amaldi received the Stanford and Louisiana proposal for a detector consisting in a 5 ton aluminum bar cooled to very low temperature (0.003 K) employing a dcSQUID amplifier coupled to a resonant transducer.

It was clear to Amaldi and me that this was the kind of experiment we should have aimed to realize."

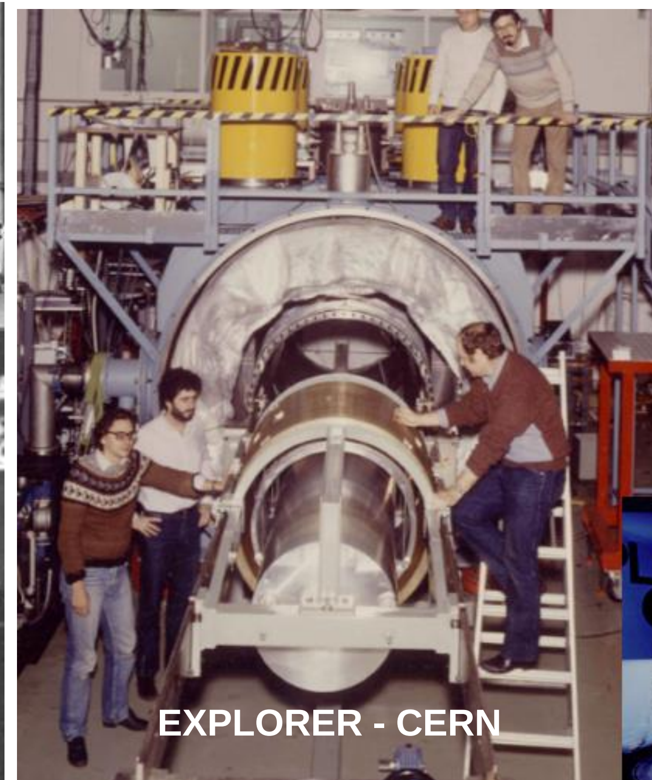
**Bill Fairbank** **Bill Hamilton**

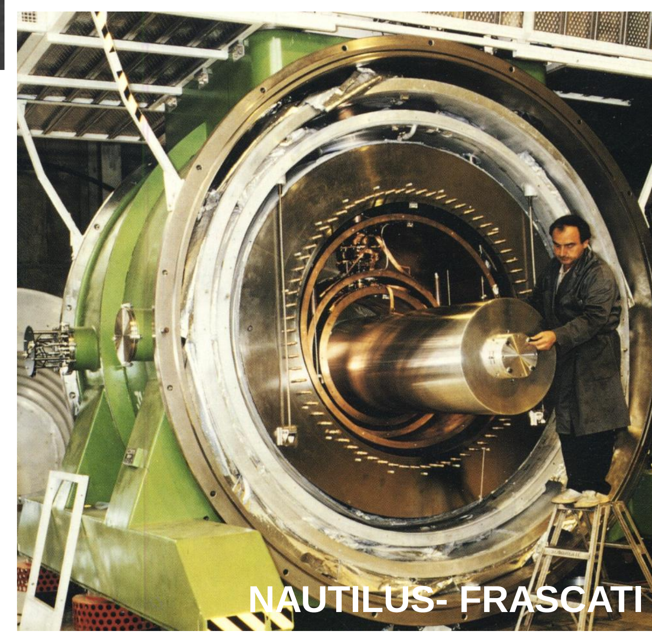
# The Rome group

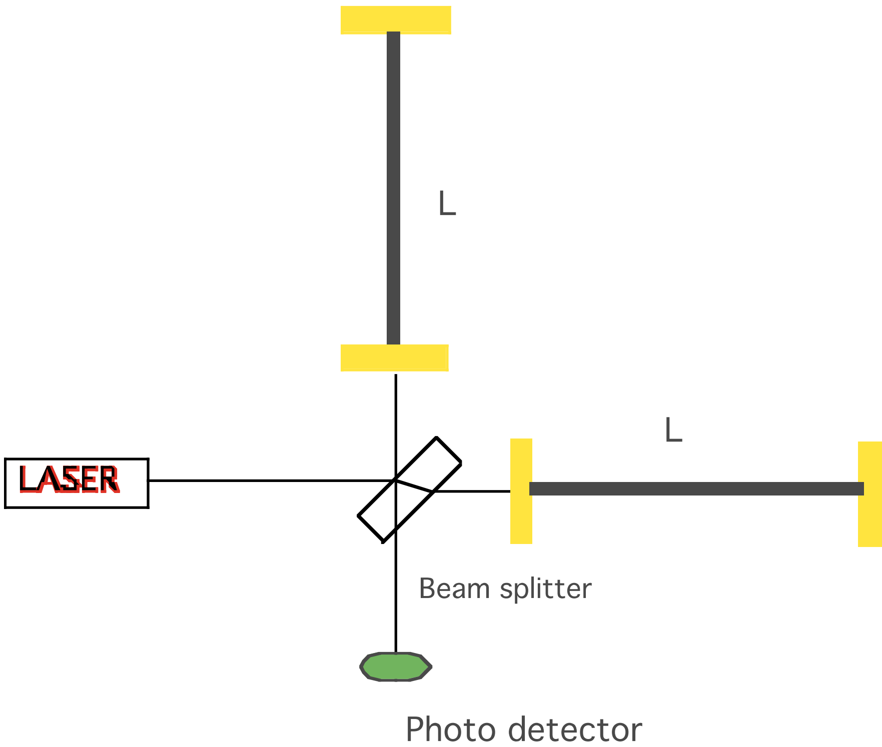
1974, (from left) Gianvittorio Pallottino and Ivo Modena

**Later**

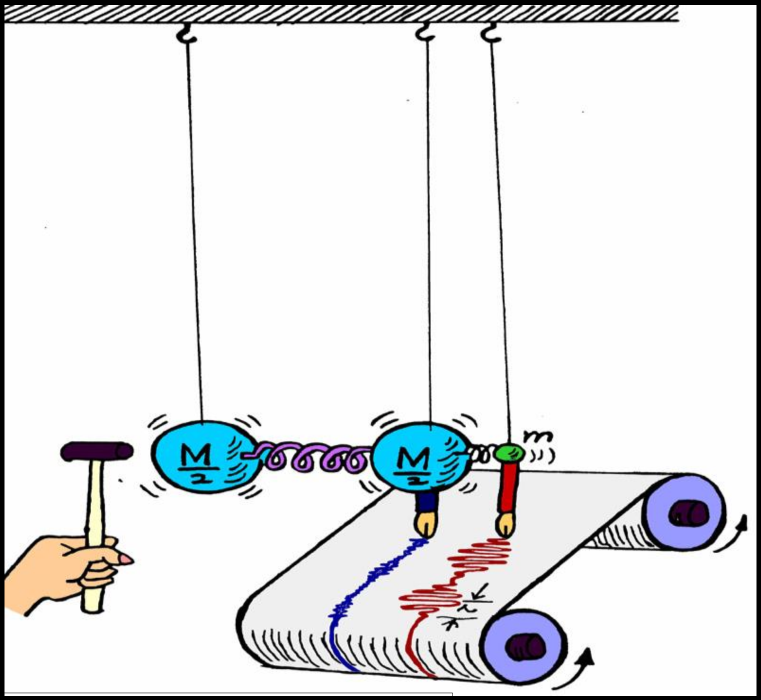
Umberto Giovanardi
Fulvio Ricci
Piero Rapagnani
Sergio Frasca
Massimo Bassan
Eugenio Coccia
Pia Astone
Viviana Fafone

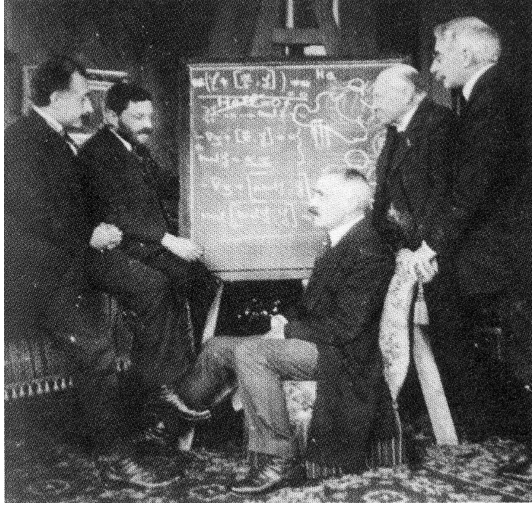





$$h = \frac{\Delta L}{L}$$





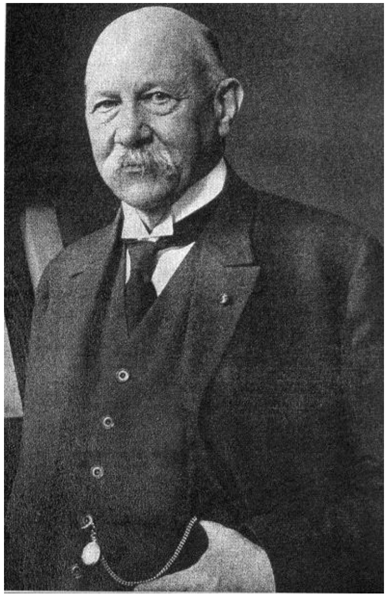
**GW hunters are heirs**
**to several great traditions**:

- high precision mechanical experiments (**Cavendish, Eotvos, Dicke**..)
  *detection of weak forces applied on mechanical test bodies*

- precision optical measurements (**Michelson, laser developpers**…)

- operation of ultraprecise measurement systems (**microwave pioneers of World War II**)

- very low temperature physics (**K. Onnes**)
  *superfluids and superconductors technology*



# ROG Collaboration

**FRASCATI:**
- Babusci
- Fafone
- Giordano
- Marini
- Modestino
- Quintieri
- Ronga
- Votano

**ROMA2:**
- Bassan
- Coccia
- D’ Antonio
- Minenkov
- Modena
- Moleti
- Pizzella
- Rocchi

**ROMA1:**
- Astone
- Cosmelli
- Frasca
- Majorana
- Pallottino
- Rapagnani
- Ricci

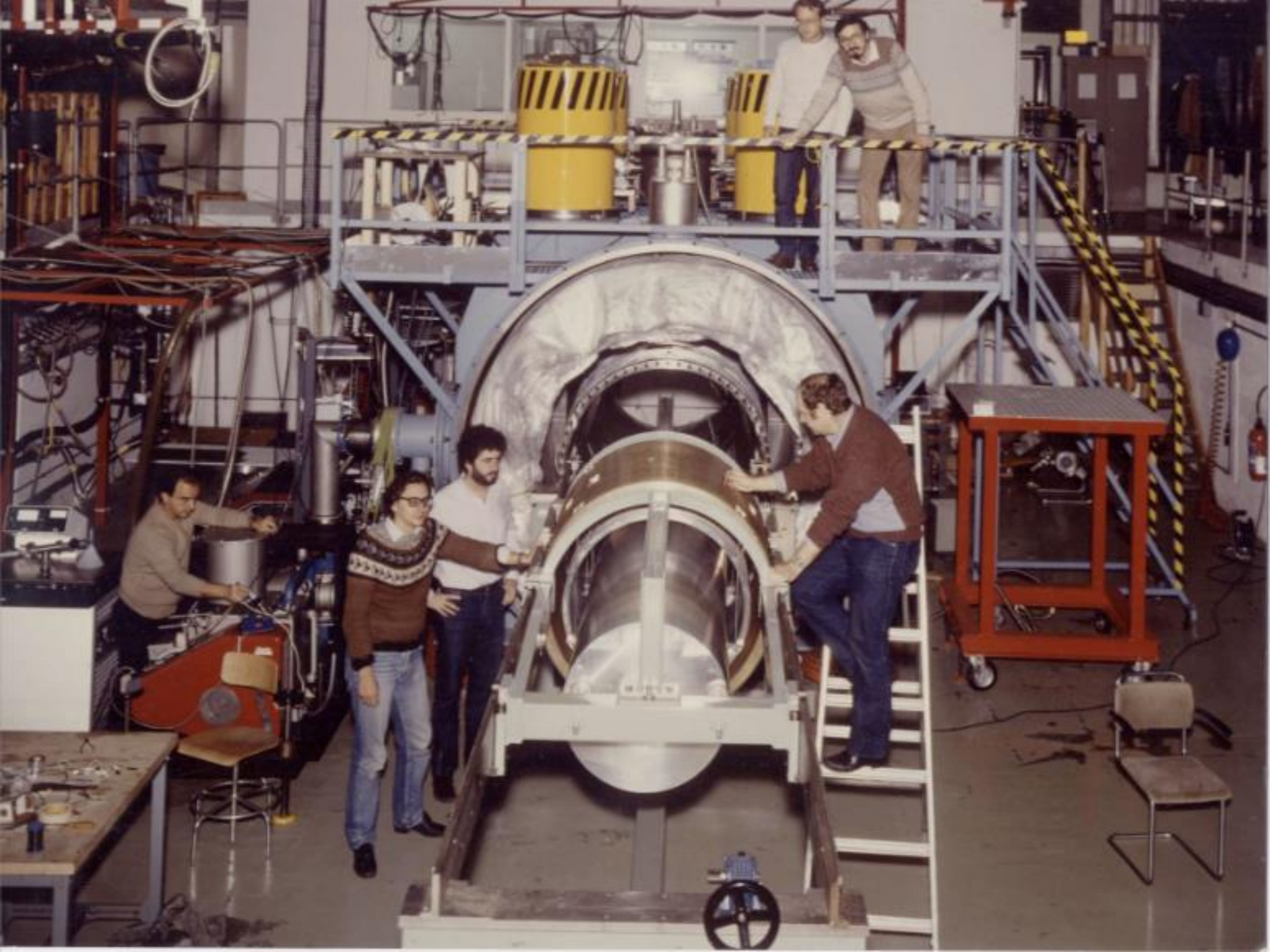
**INAF/IFSI:**
- Bonifazi
- Terenzi
- Visco

**CNR/IFN:** Torrioli

**CERN Liason**
**Vandoni**

**MoU with**
**LIGO, VIRGO, GEO, TAMA**

**Regular data exchange with**
**Auriga and Allegro (IGEC)**




gravitational wave research
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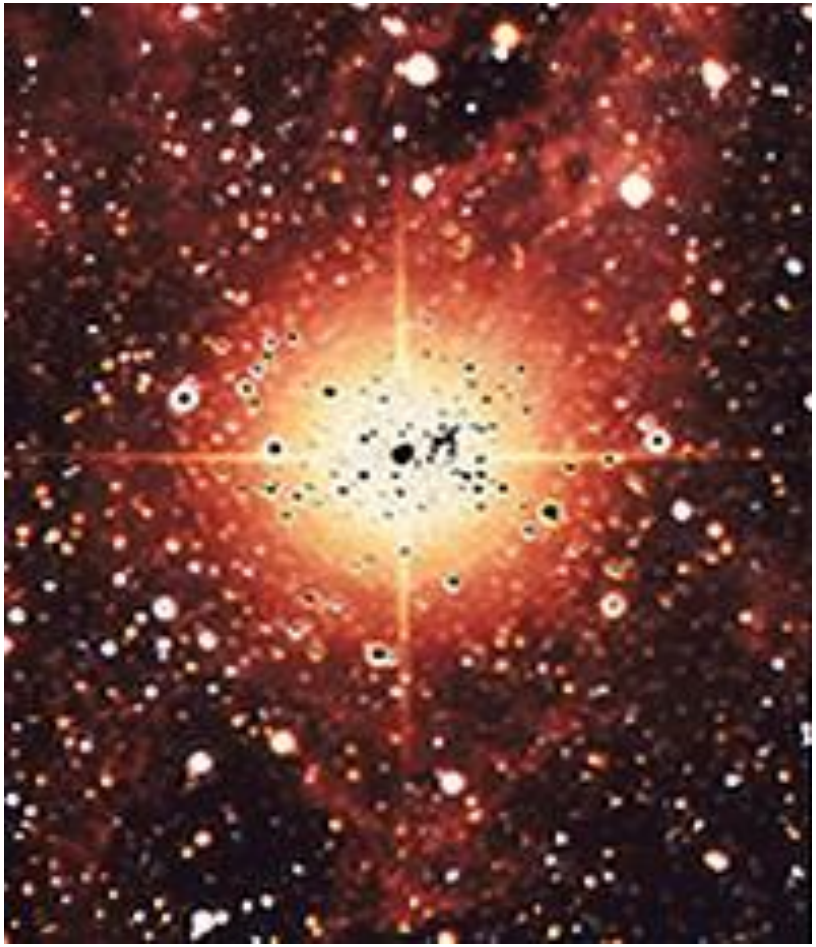
**Sn 1987a** **February 23, 1987**



**Quarter of a century ago**

# NAUTILUS
# LNF - FRASCATI

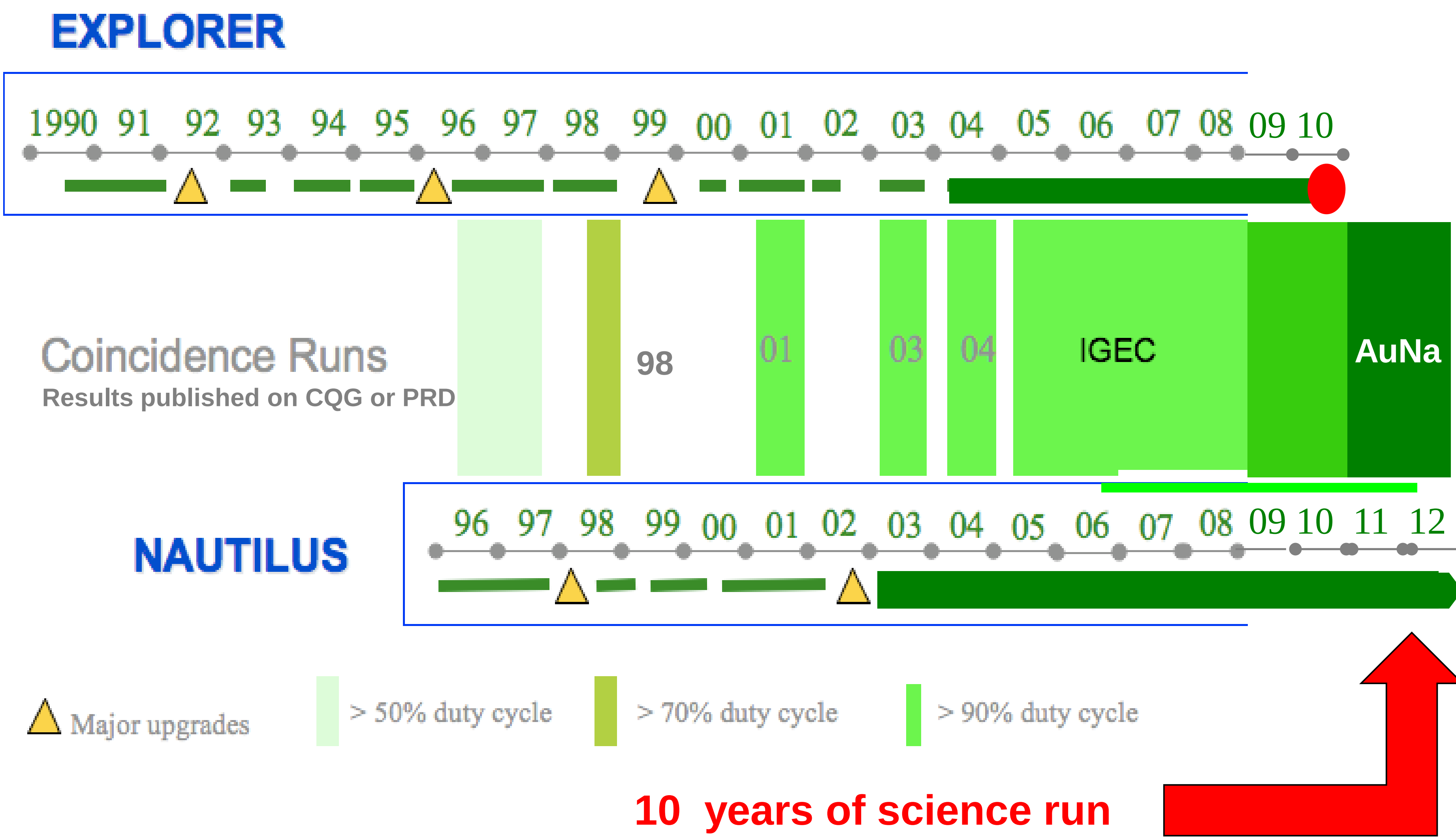
Bar Al 5056 M = 2270 kg

L = 2.91 m Ø = 0.6 m

$\nu_A$=935Hz @ T = 3 K

Cosmic ray detector

# History of E-N DATA TAKING



## First coincidence experiments

First gw coincidence experiment between three cryogenic detectors: Louisiana-Rome-Stanford
E. Amaldi et al. Astronomy & Astrophys. 216 (1989)

## Calibration with a dynamical gravitational field

Evaluation and preliminary measurement of the interaction of a dynamical gravitational near field with a cryogenic gravitational wave antenna
P. Astone et al. (ROG Collaboration) Z.Phys. C50 (1991) 21-29

## First long term operation of a gw detector ever

Long term operation of the Rome 'Explorer' cryogenic gravitational wave detector
P. Astone et al. (ROG Collaboration) Phys.Rev.D47:362-375, 1993.

## Large bandwidth resonant gravitational antennas

Increasing the bandwidth of resonant gravitational antennas
P. Astone et al. (ROG Collaboration) Phys.Rev.Lett.91:111101, 2003.

## First acoustic detection of cosmic rays

Cosmic rays observed by the resonant gravitational wave detector NAUTILUS
P. Astone et al. (ROG Collaboration) Phys.Rev.Lett.84:14-17, 2000

## First multimessenger upper limit

Search for correlation between GRB's detected by BeppoSAX and the gw detectors EXPLORER and NAUTILUS
P. Astone et al. (ROG Collaboration) Phys.Rev.D66:102002, 2002.

Astron. Astrophys. 216, 325–332 (1989)

ASTRONOMY AND ASTROPHYSICS

# First gravity wave coincidence experiment between resonant cryogenic detectors: Louisiana-Rome-Stanford

**E. Amaldi[1,3], O. Aguiar[9], M. Bassan[2,8], P. Bonifazi[3,4], P. Carelli[1,5], M.G. Castellano[3,4], G. Cavallari[7], E. Coccia[2,3], C. Cosmelli[1,3], W.M. Fairbank[8], S. Frasca[1,3], V. Foglietti[3,5], R. Habel[1,6], W.O. Hamilton[9], J. Henderson[8], W. Johnson[9], K.R. Lane[8], A.G. Mann[9], M.S. McAshan[8], P.F. Michelson[8], I. Modena[2,3], G.V. Pallottino[1,3], G. Pizzella[1,3], J.C. Price[8], R. Rapagnani[1,3], F. Ricci[1,3], N. Solomonson[9], T.R. Stevenson[8], R.C. Taber[8], and B.-X. Xu[9]**

[1] Dipartimento di Fisica dell'Universita 'La Sapienza', Piazza Aldo Moro, 2, I-00185 Roma, Italy
[2] Dipartimento di Fisica dell'Universita 'Tor Vergata', Roma, Italy
[3] Istituto Nazionale di Fisica Nucleare, Roma, Italy
[4] Istituto di Fisica dello Spazio Interplanetario del CNR, Frascati (Roma), Italy
[5] Istituto di Elettronica dello Stato Solido del CNR, Roma, Italy
[6] ENEA, Centro Ricerche Energia, Frascati (Roma), Italy
[7] CERN, European Organization for Nuclear Research, Geneva, Switzerland
[8] Department of Physics, Stanford University, Stanford, CA 94305, USA
[9] Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803-4001, USA

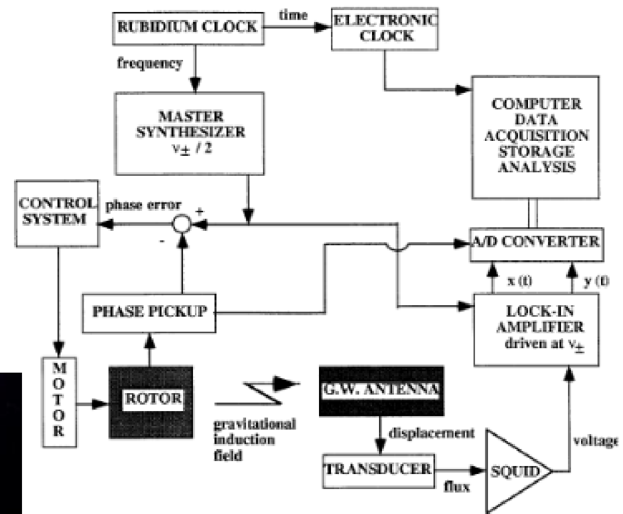
Received August 8, accepted November

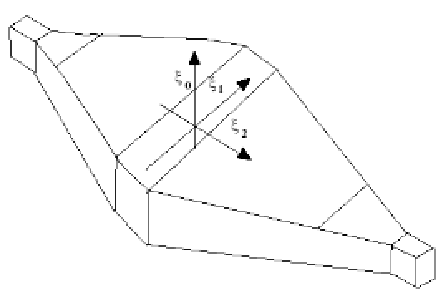
**Summary.** The results of a coincidence search for short bursts of gravitational radiation with cryogenic resonant-mass detectors are reported. No significant excess of coincidences at zero time delay were found. The data have been used to set an improved observational upper limit on the flux of impulsive gravitational waves that may be impinging on the Earth.

# Detector calibration - Deviation from Newton law

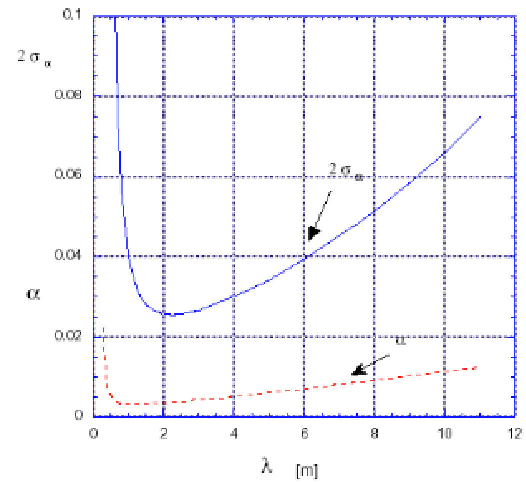
*Evaluation and preliminary measurement of the interaction of a dynamical gravitational near field with a cryogenic gravitational wave antenna.*
P. Astone et al. (ROG Collaboration)

**Z.Phys.C50:21-29, 1991**



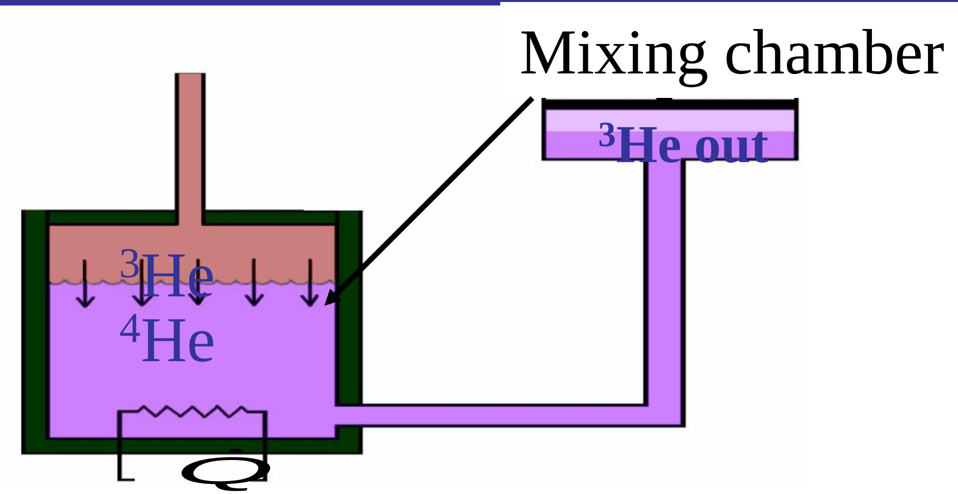
$$V = -\frac{Gm}{r}\left(1 - \alpha e^{-r/\lambda}\right)$$

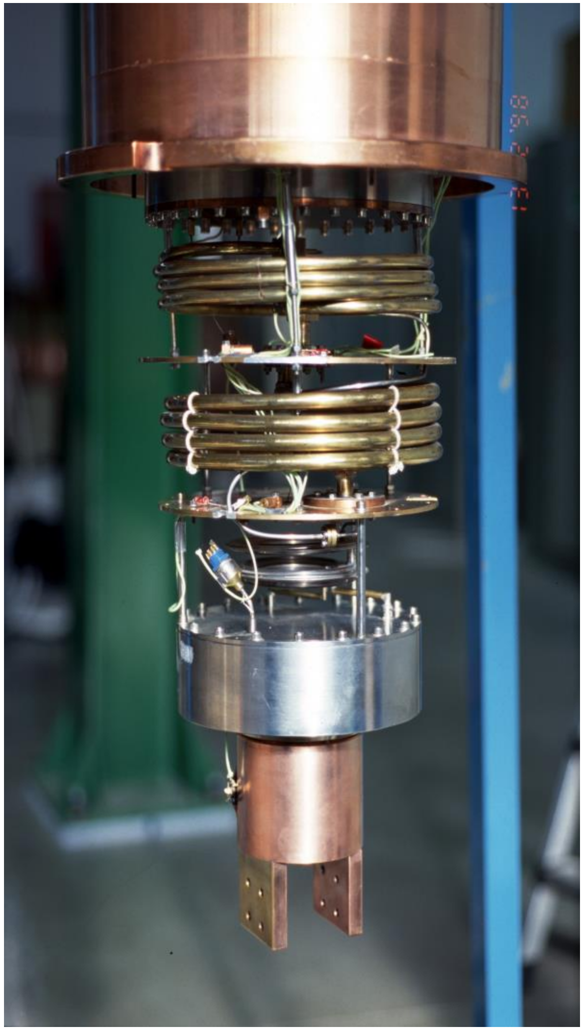



**NAUTILUS**
**Largest mass cooled below 0.1 K**

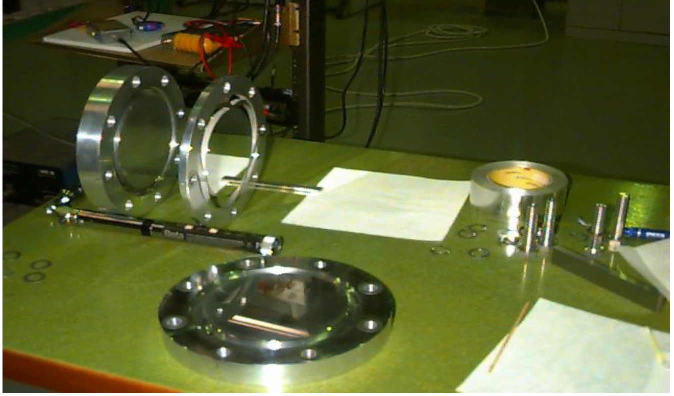
# $^3He$-$^4He$ Dilution Refrigerator

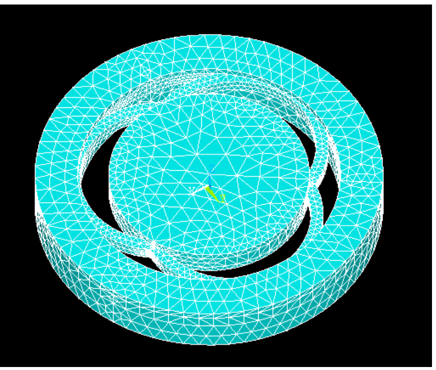
The liquid (the concentrated $^3He$ phase) is lighter and floats on a $^4He$ sea, in equilibrium with the 6.5% "vapor". When $^3He$ passes from the low entropy liquid to the vapor phase (high entropy) it expands and absorbs heat.

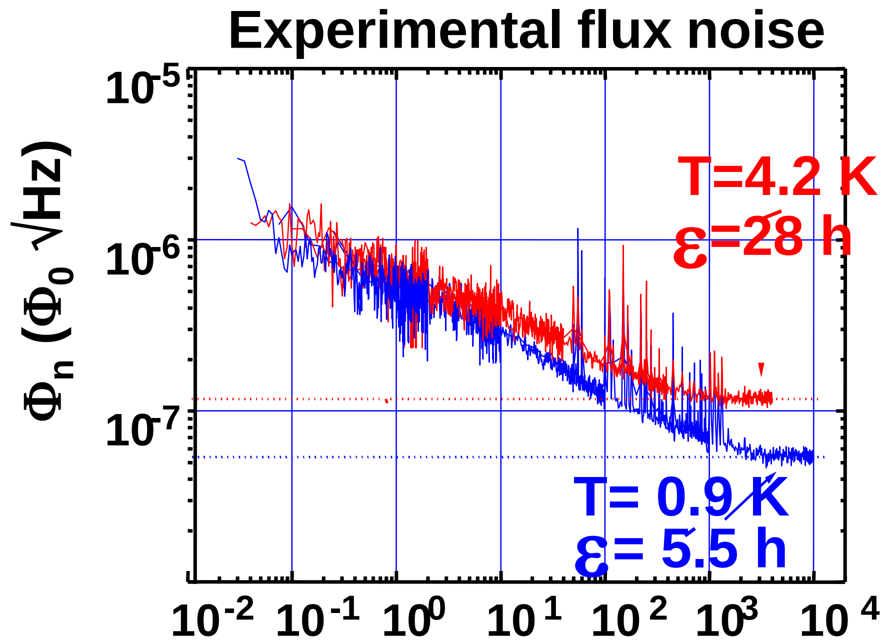


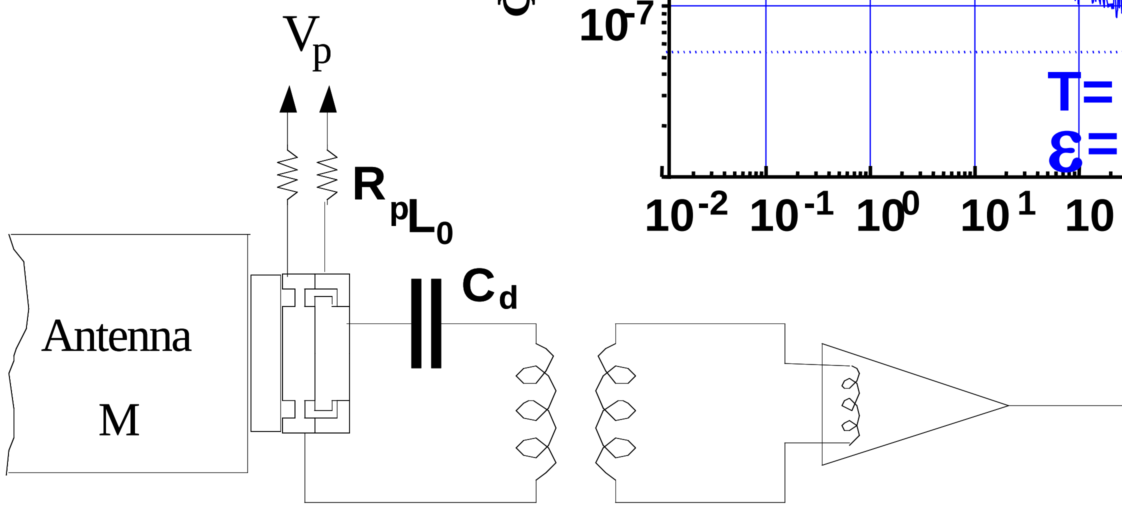



He-3 / He-4 mixing chamber for an ultralow temperature gw antenna.
E. Coccia, I. Modena Cryogenics 31:712-714,1991.








Yuri Minenkov

**Capacitive transducer**

**Al 5056**
**$m_t$ = 0.75 kg**
**$\nu_t$= 916 Hz**
**$C_t$ = 11 nF**
**E = 5 MV/m**

**Superconducting Low-dissipation Transformer**

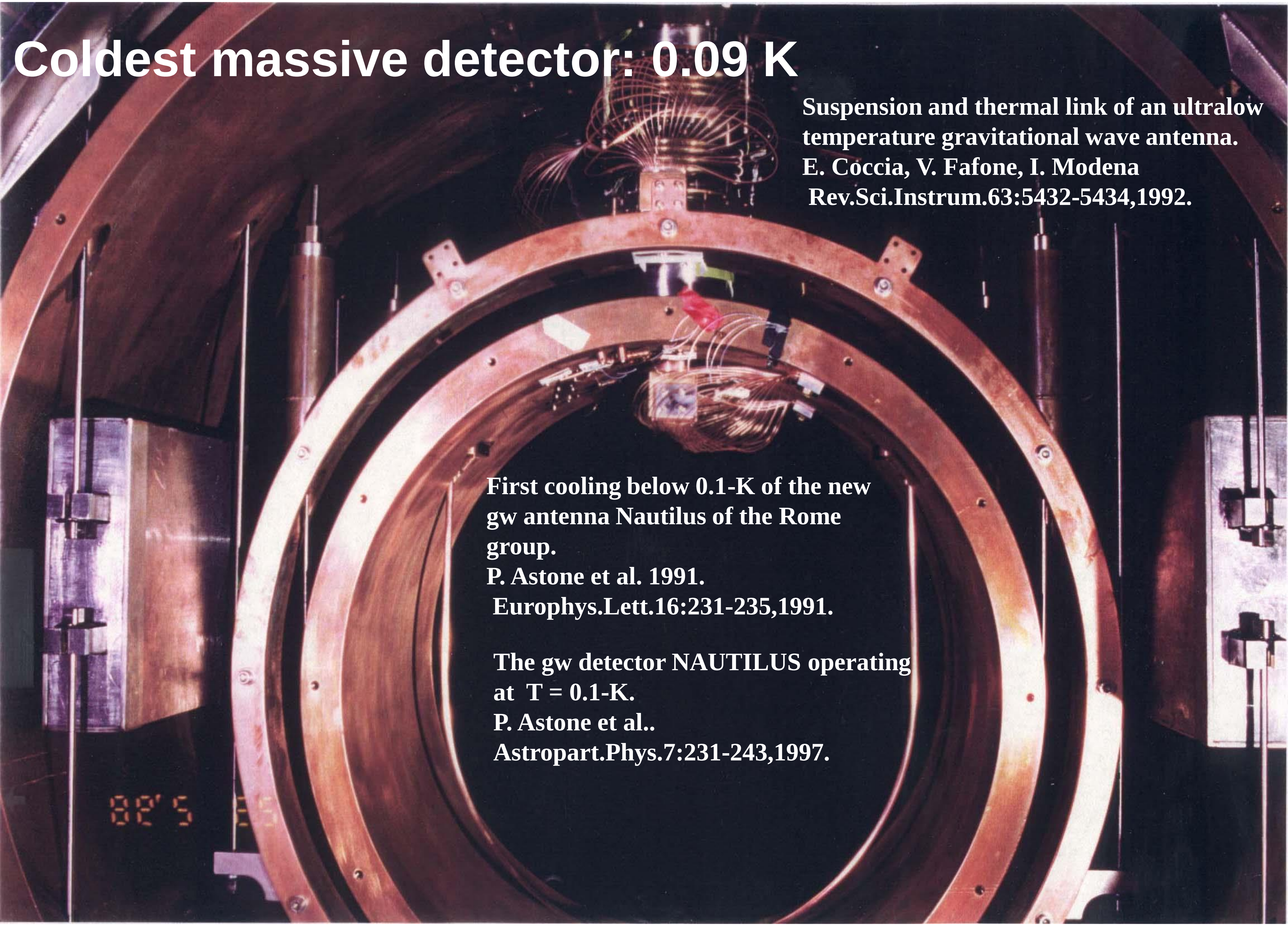
**Lo=2.86 H**
**Li=0.8μH**
**K=0.8**

Alessio Rocchi

**dc-SQUID**

**$M_s$ = 10 nH**
**$\Phi_n$= 3 ·$10^{-6}$ $\Phi$o/√Hz**

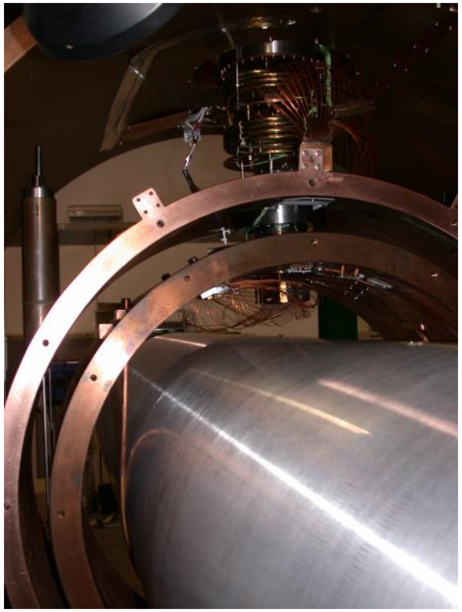
# Coldest massive detector: 0.09 K



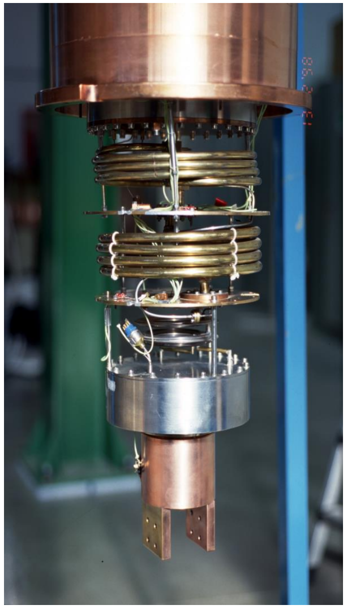
**Suspension and thermal link of an ultralow temperature gravitational wave antenna.**
**E. Coccia, V. Fafone, I. Modena**
**Rev.Sci.Instrum.63:5432-5434,1992.**

**First cooling below 0.1-K of the new gw antenna Nautilus of the Rome group.**
**P. Astone et al. 1991.**
**Europhys.Lett.16:231-235,1991.**

**The gw detector NAUTILUS operating at T = 0.1-K.**
**P. Astone et al..**
**Astropart.Phys.7:231-243,1997.**



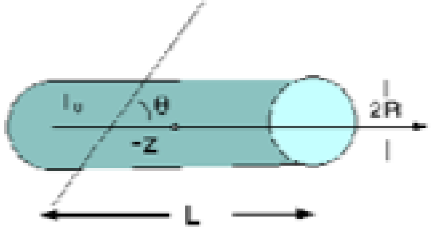
# The three Records of NAUTILUS



- **Coldest massive detector (for more than 20 years)**

2.5 tons at 90 mK

***Europhys. Lett.16, 231 (1991)***




- **First acoustic detection of cosmic rays**

Proving the Cabibbo thermo-acoustic theory

***Phys. Rev. Lett. 84, 14 (2000)***

Upper limits to nuclearites and quark nuggets

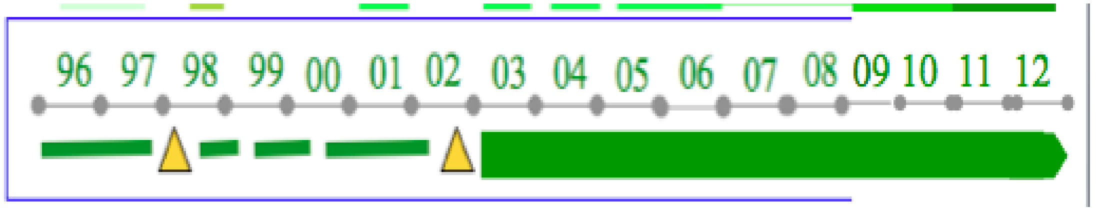
***Phys.Rev. D47:4770-4773 (1993); ICRC 2013***

- **Longest science run for GW detectors**

12 years of continuous data taking

***Phys. Rev. D 82, 22003 (2010)***

***Phys. Rev. D87 082002 (2013)***




Gravitational Wave Detectors
MiniGRAIL
The Netherlands
Allegro, USA
Auriga,
Italy
MINIGRAIL
GEO
AURIGA
EXPLORER
NAUTILUS
LIGO
ALLEGRO
LIGO
EXPLORER
Explorer
Switzerland
Nautilus, Italy
Schenberg,
Brazil
MARIO SCHENBERG
AIGO
NIOBE
Niobe
Australia

GWIC
Gravitational Wave International Committee

https://gwic.ligo.org/

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- Thesis Prizes
- Statements
- Conferences
- GWIC meetings
- Reports to IUPAP
- Simulation Programs
- GWIC By-laws
- Members
- Related Links

## The Gravitational Wave International Committee:

GWIC, the Gravitational Wave International Committee, was formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities world-wide. It is associated with the International Union of Pure and Applied Physics as its Working Group WG.11. Through this association, GWIC is connected with the International Society on General Relativity and Gravitation (IUPAP's Affiliated Commission AC.2), its Commission C19 (Astrophysics), and another Working Group, the AstroParticle Physics International Committee (APPIC).

## GWIC's Goals:

- Promote international cooperation in all phases of construction and scientific exploitation of gravitational-wave detectors;
- Coordinate and support long-range planning for new instrument proposals, or proposals for instrument upgrades;
- Promote the development of gravitational-wave detection as an astronomical tool, exploiting especially the potential for multi-messenger astrophysics;
- Organize regular, world-inclusive meetings and workshops for the study of problems related to the development and exploitation of new or enhanced gravitational-wave detectors, and foster research and development of new technology;
- Represent the gravitational-wave detection community internationally, acting as its advocate;
- Provide a forum for project leaders to regularly meet, discuss, and jointly plan the operations and direction of their detectors and experimental gravitational-wave physics generally.

## More about GWIC:

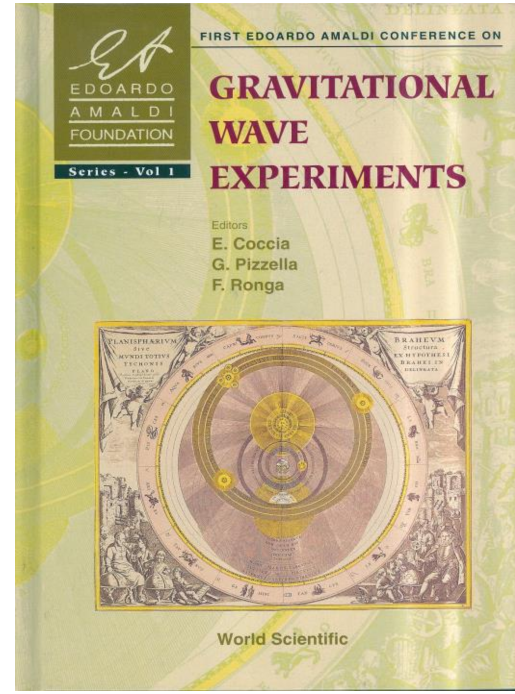
GWIC - Ten Years on (PDF) reprinted from Matters of Gravity (Fall 2007),
the newsletter of the Topical Group on Gravitation of the American Physical Society.

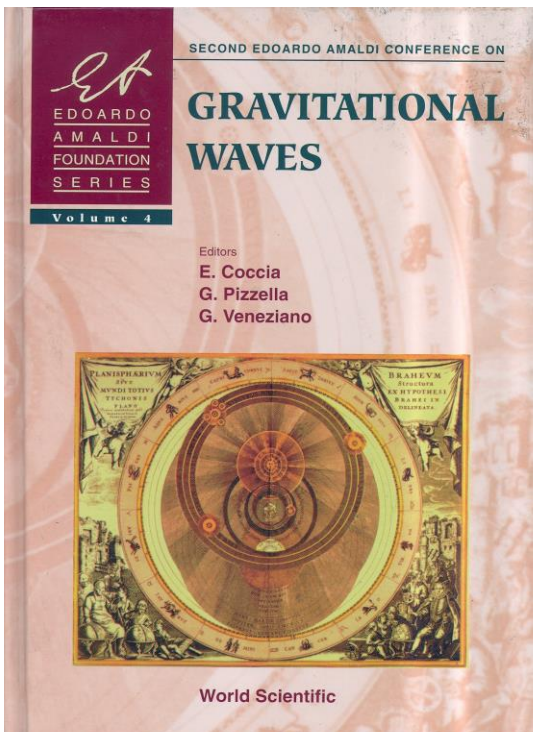
**News**

- GWIC is now an IUPAP Working group (WG11)
- Progresses towards LIGO-India
- GWIC thesis Prize named after Stefano Braccini

## The Edoardo Amaldi Conference series on Gravitational Waves

In 1993 Nautilus, the first ultracryogenic bar detector, started operating at the INFN Frascati Lab. It was natural to organize a new conference on GW experiments in Frascati, and to dedicate it to Amaldi. The idea was that this conference could be the first of a series. So the first EA conference was held in Frascati in 1994, with 120 participants from 13 countries.




The second edition was held at CERN in 1997, with a massive participation of the GW community. During the conference, the Gravitational-Wave International Committee (GWIC) was formed, under the chairmanship of Barry Barish. Barry agreed to organize the third edition in the US.
Since then, Caltech 1999, EAC is biennial and coordinated by GWIC as the cornerstone conference for the GW community worldwide.

# The phase change and the future

**1960 - 2005**
**Given the uncharted territory that gravitational-wave detectors are probing, unexpected sources may actually provide the first detection.**

**2005 -**
**Only new high sensitivity detectors can provide the first detection and open the GW astronomy**

**The contribution of Resonant Bars has been essential in establishing the field, giving interesting results and putting some important upper limits on the gravitational landscape around us, but now the hope for guaranteed detection is in the Network of long arm interferometers.**

# *AuNa*

## Attività e persone di riferimento

- Coordinare la presa dati di AU e NA.
- Scambiare i dati h(t) calibrati con Data Quality per circa una giornata intorno al tempo di trigger.
- Analizzare i dati con algoritmi diversi, ma concordando le metodologie generali comuni.

Coordinamento dei runs (Taffarello - Fafone)

Calibrazioni (Zendri - Rocchi)

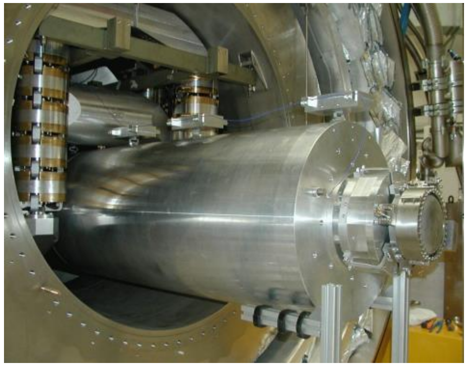
Selezione dei trigger astrofisici (Cerdonio - Coccia)

Analisi dei dati e redazione di reports (Prodi, Vedovato - Giordano, Visco)

- **NAUTILUS**
  - 95% duty cycle
  - monitor of strong gw sources in the Galaxy
  - data *validated* by cosmic ray acoustic effect
  - study of coincidences in long runs

- **AuNa**: NAUTILUS and AURIGA in continuous and coordinated operation, with the goal of searching for strong galactic sources during the period not covered by long arm interferometers.

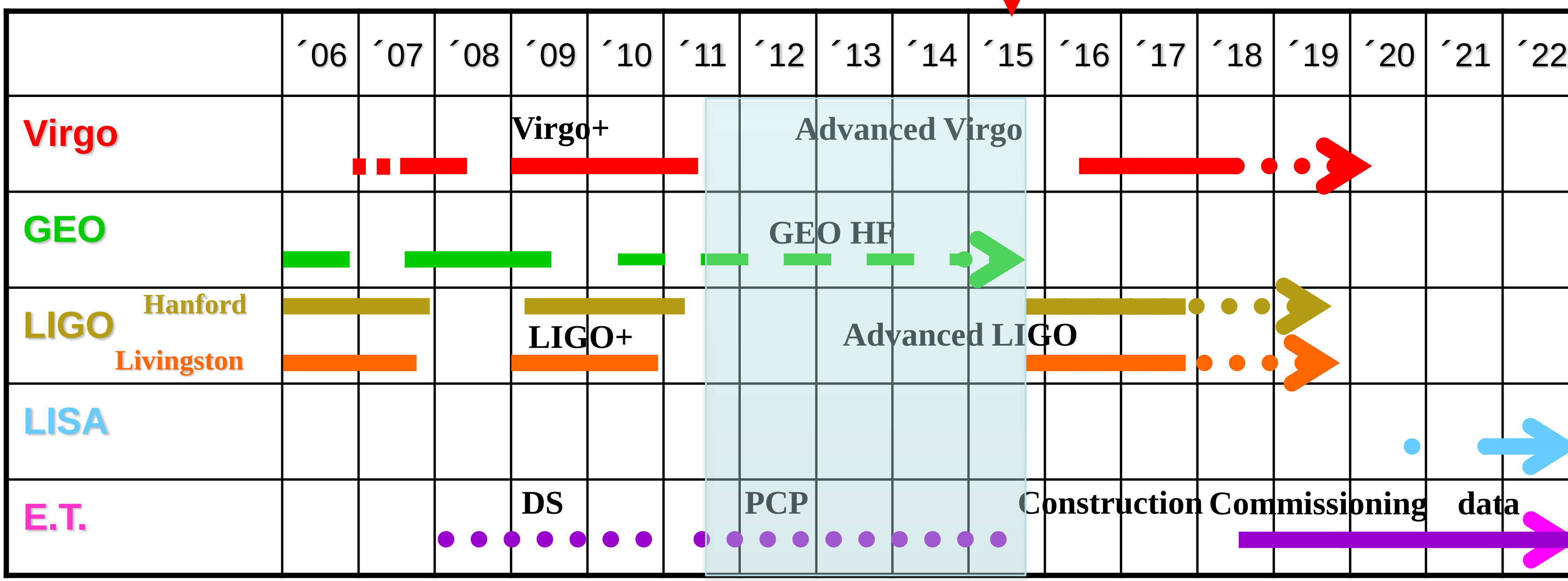
AURIGA - LNL



# AUNA

NAUTILUS - LNF

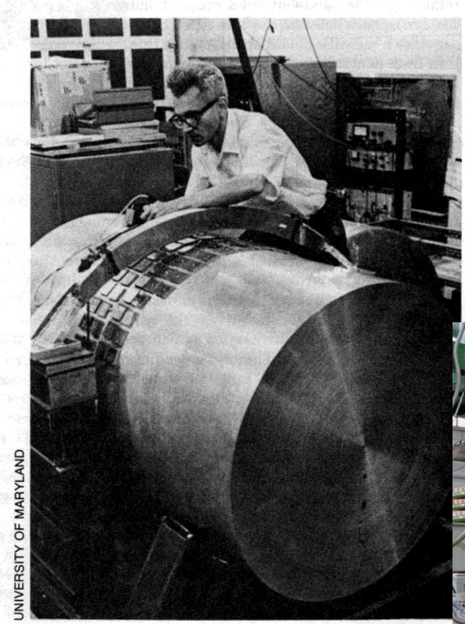
We are here




*Window of opportunity*
*for AURIGA and NAUTILUS*

# Some perspective: 50 years of attempts at detection:

Since the pioneering work of Joseph Weber in the ‘60, the search for Gravitational Waves has never stopped, with an increasing effort of manpower and ingenuity:




60’: Joe Weber pioneering work

90’: Cryogenic Bars

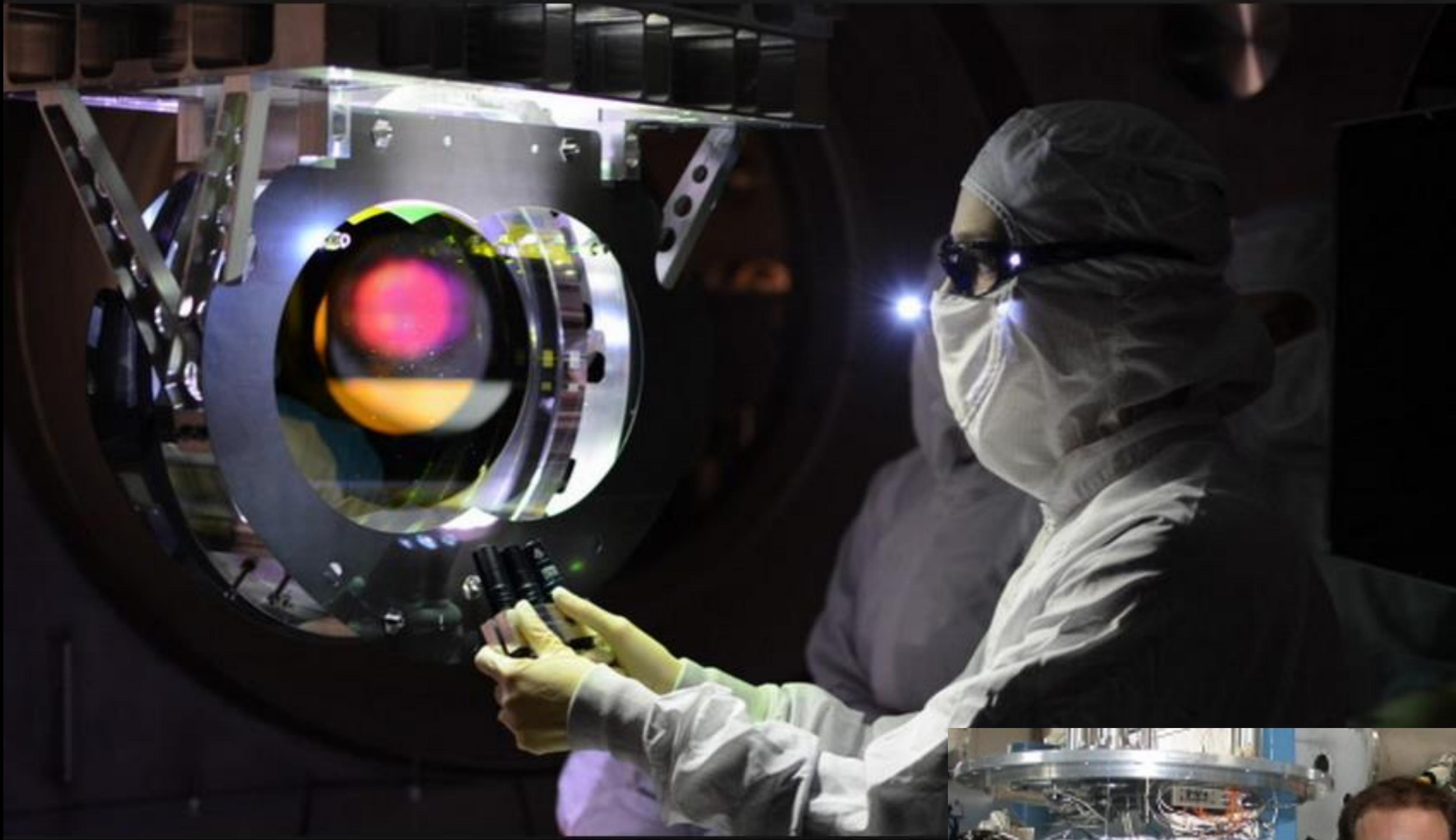
2000’ - : Large Interferometers

1997: GWIC was formed

# Virgo Collaboration

- 5 European countries, 19 labs, ~250 members
- Scientists from Italy and France (former founders of Virgo), The Netherlands, Poland and Hungary

APC Paris
ARTEMIS Nice
EGO Cascina
INFN Firenze-Urbino
INFN Genova
INFN Napoli
INFN Perugia
INFN Pisa
INFN Roma La Sapienza
INFN Roma Tor Vergata
INFN Trento-Padova
LAL Orsay – ESPCI Paris
LAPP Annecy
LKB Paris
LMA Lyon
NIKHEF Amsterdam
POLGRAW(Poland)
RADBOUD Uni. Nijmegen
RMKI Budapest
INFN GSSI

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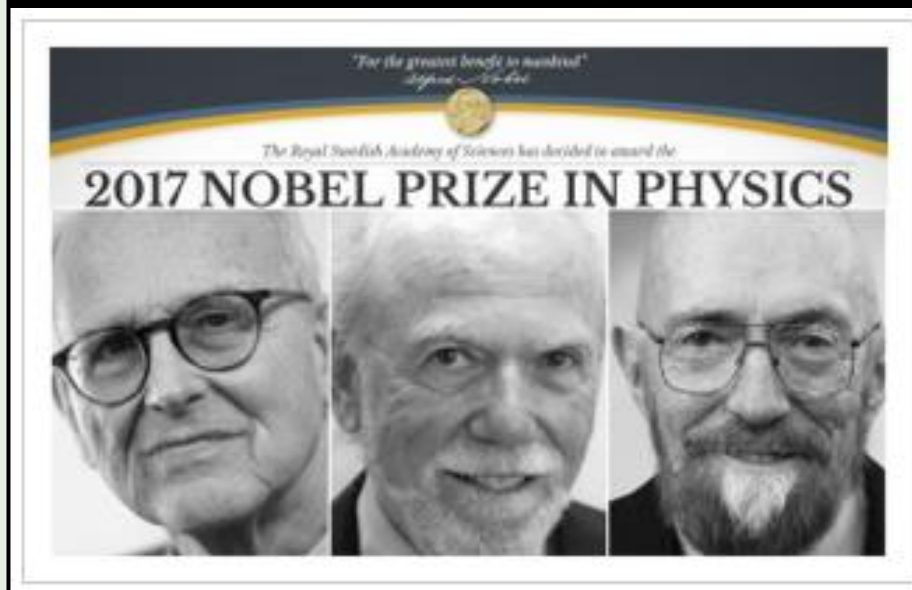
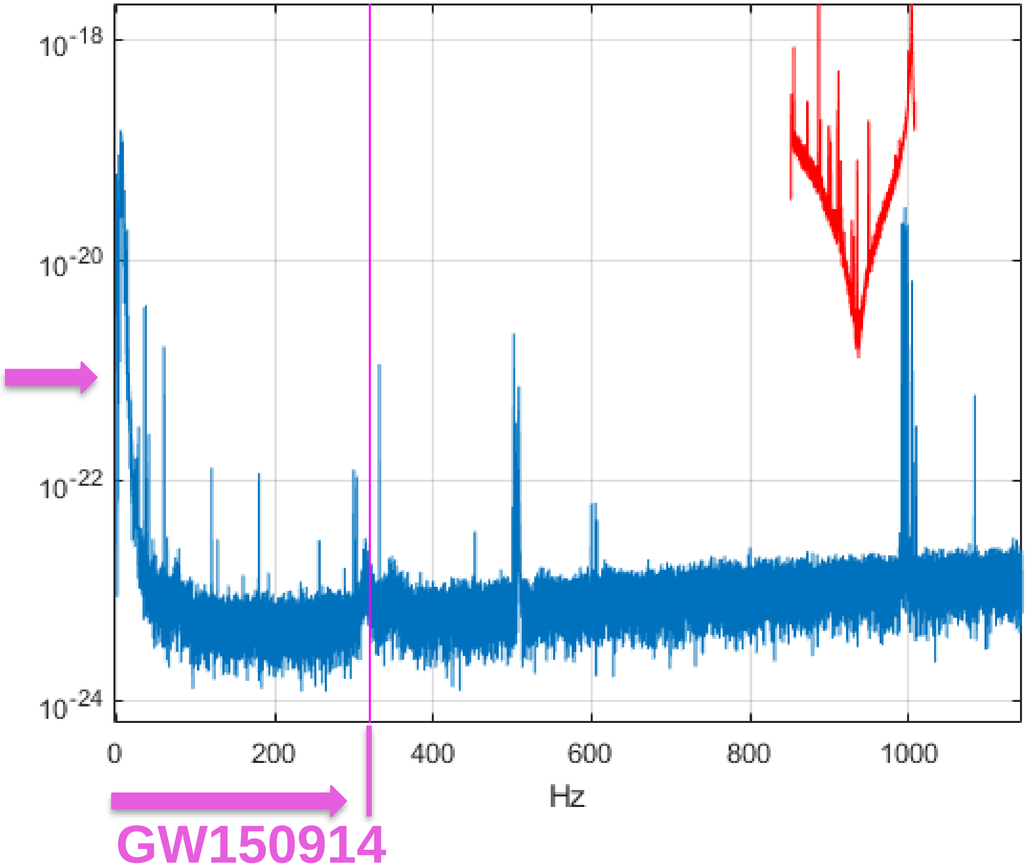
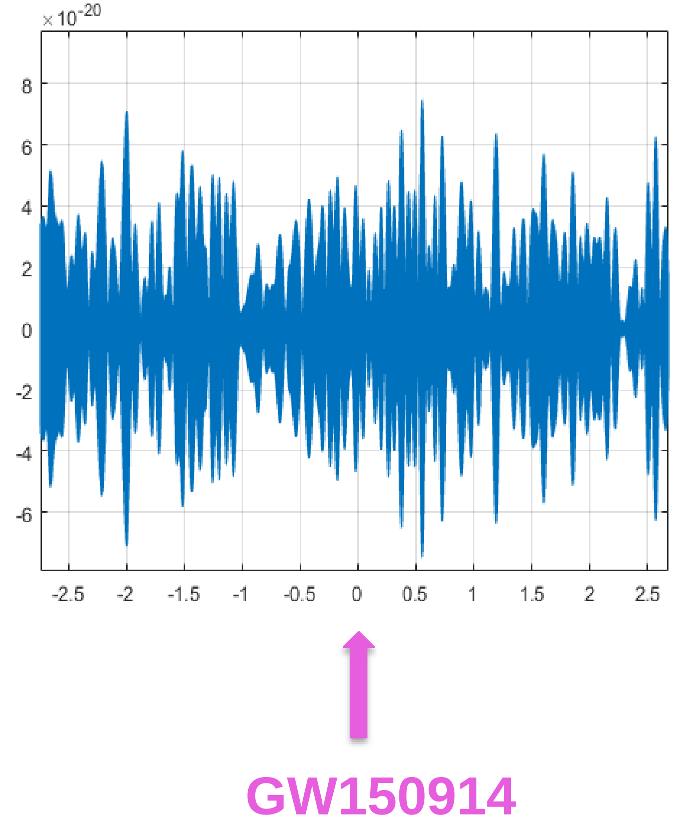
Volume 116, Number 6

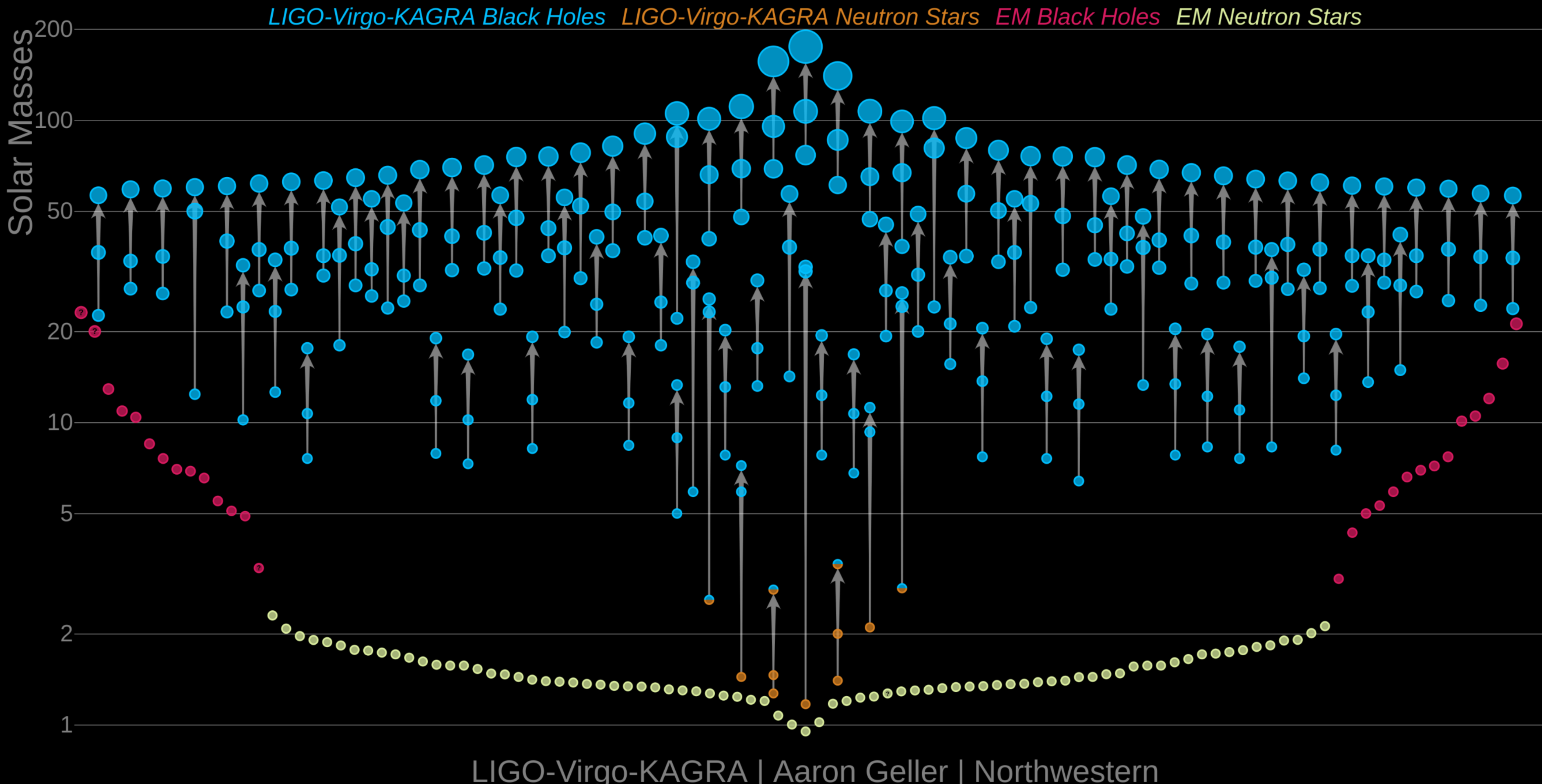


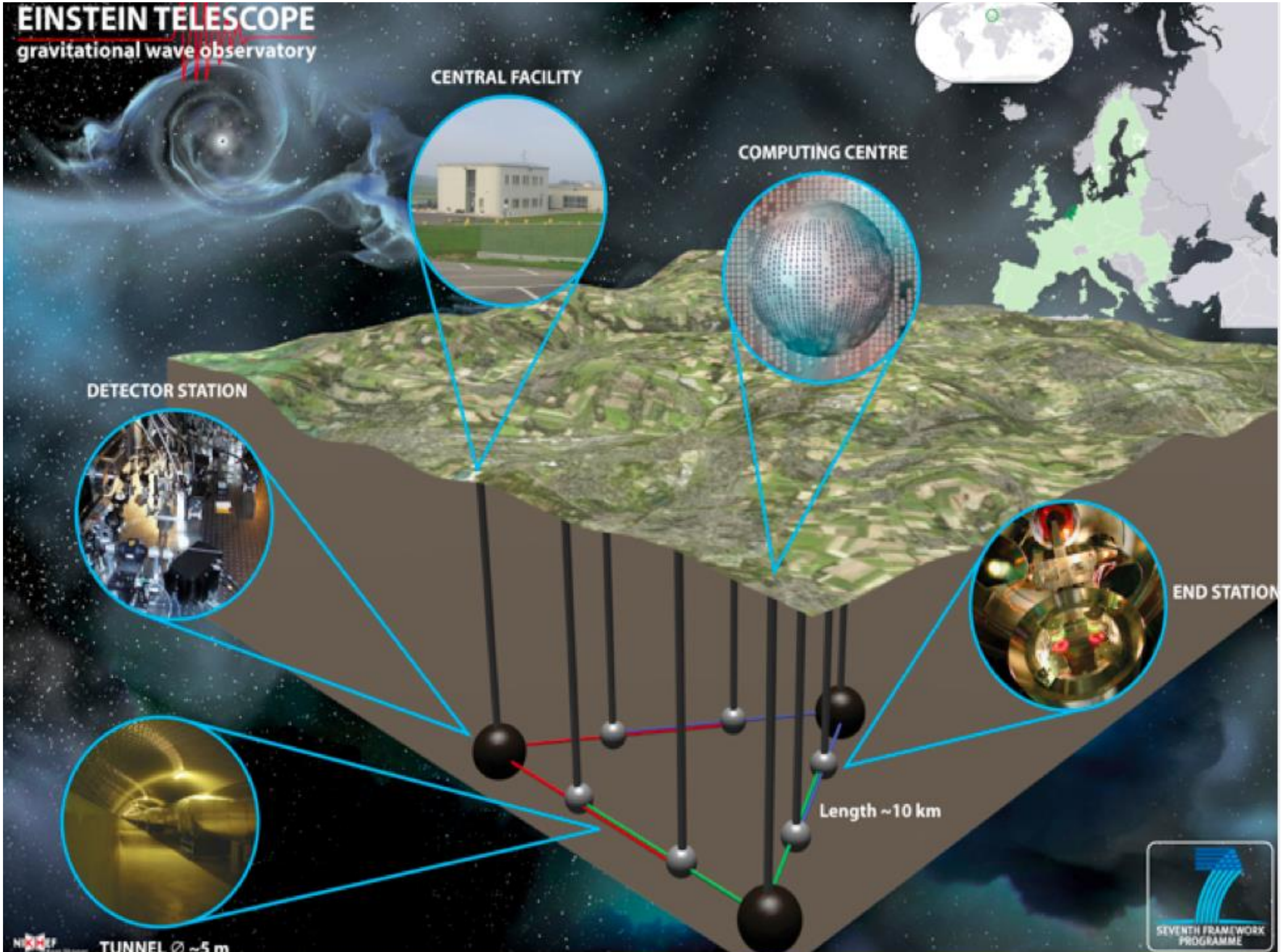
# Nautilus - September 14, 2015



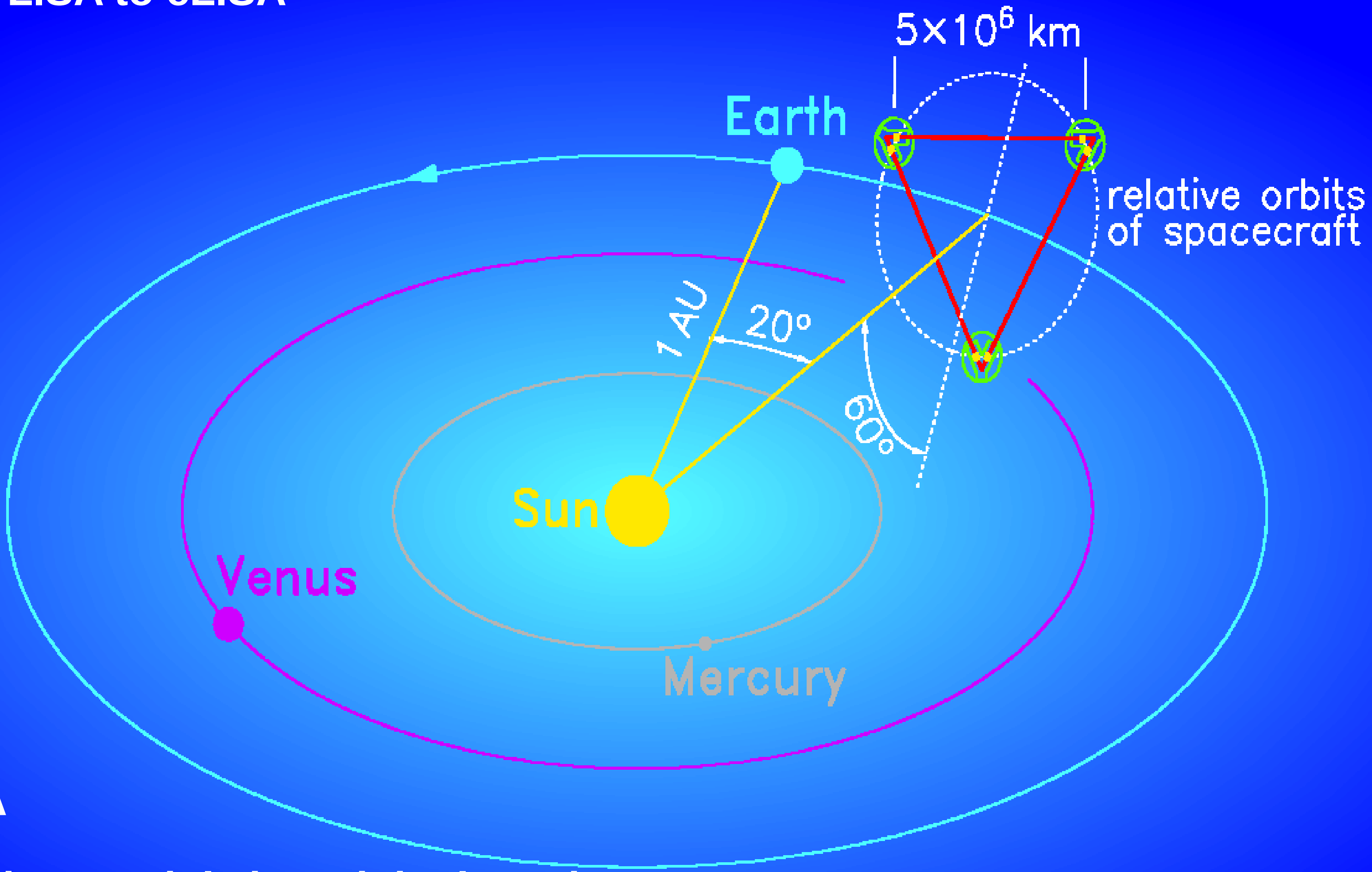



# Masses in the Stellar Graveyard




EINSTEIN TELESCOPE
gravitational wave observatory
CENTRAL FACILITY
COMPUTING CENTRE
DETECTOR STATION
END STATION
Length ~10 km
TUNNEL ∅ ~5 m
SEVENTH FRAMEWORK PROGRAMME

## From LISA to eLISA




**eLISA**

- **Savings mainly in weight, launch cost.**
- **Two active arms, not three;**
- **Smaller arms (1Gm, not 5Gm);**
- **Re-use LISA Pathfinder hardware;**

# 2030?